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NOTES ON DEEP-WATER ATLANTIC CRINOIDEA

By AILSA M. CLARK

SYNOPSIS

Notes are given on some little-known species of the stalked crinoid family Bathycrinidae from the north, equatorial and south-west Atlantic, including *Bathycrinus aldrichianus*, *B. australis* and the type-species, *B. gracilis*, collected by the U.S. research vessels *Atlantis II* and *Chain*, and *Democrinus parfaiti*, collected by the R.R.S. *Shackleton*. In addition a corrected type citation for *Bathycrinus carpenteri* is given and notes on the type material of *Democrinus brevis* in the British Museum collections. A post-pentacrinoid of *Atelecrinus* is figured and new records cited for a few other species of unstalked crinoids, including the deepest to date for the Mediterranean species *Leptometra phalangium*.

INTRODUCTION

THE small but interesting collection of crinoids which forms the basis for much of this paper was collected by the Wood's Hole Oceanographic Institution. It was forwarded to the British Museum by Dr D. L. Pawson of the Smithsonian Institution who received it from Dr H. Sanders of Wood's Hole. The *Shackleton* material of *Democrinus parfaiti* was presented by Dr J. D. George of this museum. I am indebted to all of them.

About two-thirds of the American material is being returned to the Smithsonian, the remainder being retained for the British Museum collections.

Unfortunately the small size and vulnerability of most of the crinoids concerned prevented positive specific identifications of some specimens. However, the material did allow some studies on the early growth stages. Most important, it includes two mature crowns of *Bathycrinus gracilis* Wyville Thomson – the type-species of the genus, described from an immature specimen which has been lost.

DESCRIPTION OF SPECIES

Order MILLERICRINIDA

Family **BATHYCRINIDAE**

Bathycrinus aldrichianus Wyville Thomson

(Fig. 1g)

Bathycrinus aldrichianus Wyville Thomson, 1876 : 47–51, fig. 1 ; 1877 : 92–95, fig. 23 ; Gislén, 1938 : 15–16 ; A. H. Clark, 1949 : 377 ; Gislén, 1951 : 51–53 ; Macurda & Meyer, 1976 : 647–666.*

Bathycrinus campbellianus P. H. Carpenter, 1884 : 238–240, fig. 15.
Bathycrinus serratus A. H. Clark, 1908 : 205–207, fig. 1.

MATERIAL. *Challenger* st. 106, 01°47′N, 24°26′W (about midway between Cape Verde and the NE. corner of Brazil), 3382 metres ; the holotype (crown only) BM (NH) reg. no. 85.3.30.34.

* Thanks to Dr Macurda I have seen a typescript of this paper, which records new material of *B. aldrichianus* from 00°12′N, 05°11′E, in the Gulf of Guinea at 3595 metres, including several adult specimens with the basal ring and upper part of the stalk still attached to the crown. The authors give a detailed description, mainly of the fine structure of the articulations, as studied by SEM.

Atlantis II cruise 60, st. 259A & D, 37°13'S, 52°45'W (off Argentina, SE. of Rio de la Plata), 3305–3317 metres ; 2 crowns.

Chain cruise 50, st. 85, 37°59.2'N, 69°26.2'W (SE. from New York), 3834 metres ; 1 small armless specimen.

The specimen with basal ring and at least the proximal part of the stalk (Fig. 1g) is very small and has broken above the radials which themselves appear to be only partially regenerated. It has the five uppermost columnals discoidal (height not more than a sixth of the breadth). Macurda & Meyer (1976) note that there are 'at least 5 but usually 12 or more short proximal columnals . . . with a synostosial articulation between them.' Clearly, Carpenter (1884) was right to reject as genuine the long-segmented column drawn juxtaposed to the crown of the holotype by Wyville Thomson's artist.

Like the holotype, both crowns from the *Atlantis II* have strongly grooved surfaces to the division series and brachials and all these ossicles are markedly flared at their distal ends producing a very serrated profile. The surface of the radials has a fingerprint-like texture with much finer grooving, similar to that of *B. gracilis*. Even the syzygial joints have their proximal elements flared so the syzygies (or cryptosynarthries according to Macurda & Meyer) are not easy to distinguish. The first three brachial ones are usually at 1+2, 4+5 and 6+7 but a total of four (possibly five) arms out of twenty have the second syzygy at 3+4, as in *Monachocrinus*. Conversely, the distal joint of Br_6 is muscular on six arms. Because of this variation, the position and identity of the first pinnule vary considerably. On one specimen it is P_3 in every case but on six arms it arises on Br_9 and on three on Br_8. The second specimen has P_3 present only on three arms, once on Br_9 and twice on Br_{10} (when five syzygies precede it) ; otherwise the first pinnule is P_c, usually on Br_{10} (preceded by only four syzygies) but once on Br_{11}. On both specimens the first pinnules have 10 or 11 segments and measure 4·2–4·5 mm. The longer pinnules, such as P_5, have 15 or 16 segments and measure 6·0–6·5 mm.

Other numerical data for these specimens are given in Table 1 with the values for the holotype, which is of similar size and has the first pinnule P_c or P_3 on Br_9 or Br_8. It is therefore surprising that Gislén's much larger Swedish Deep-Sea Expedition specimen (1951) with the crown 56 mm long has the first pinnule on Br_{11}. (This is P_4 since Br_9 as well as Br_3 and Br_6 have muscular joints at both ends.) It is possible that there is not a progressive development of the more proximal pinnules during growth in this species, as there appears to be in *Democrinus parfaiti*.

Affinities. As mentioned under *B. gracilis*, both that species and *B. aldrichianus* have very serrated profiles to the crowns. The ornamentation of the ossicles of *B. gracilis* is more restricted to a central keel, with only traces of other fluting, but this could be correlated with the somewhat smaller size. Possibly further material may indicate that only one species can be recognized.

Distribution. The *Atlantis II* record provides an extension of range to the southwest Atlantic off northern Argentina from the equatorial Atlantic and overlaps with the new extension to the range of the much larger smooth species of southern *Bathycrinus*, *B. australis* A. H. Clark. Other records are off the United States,

TABLE 1

Numerical data from *Bathycrinus* spp.

Specimen number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
STALK :															
No. discoidal cols.	..	..	..	..	..	10	9	..	10	13	..	12	9	18	11
1st col. height> breadth	..	..	..	..	..	24	25	..	..	27	..	..	..	35	26
Min. prox. breadth	..	..	..	..	..	2·0	1·9	1·8	1·6	1·3	..	1·6	1·7	1·1	1·0
CALYX :															
Height (basals and radials)	..	..	..	..	..	4·5	4·4	4·6	4·0	3·9	3·8	4·2	4·2	3·3	3·2
Basals height	..	..	..	..	..	1·1	1·2	0·8	1·2	1·0	0·9	1·1	1·0	1·1	1·1
Basals lower breadth	..	..	..	..	..	2·25	2·2	2·2	1·9	1·7	1·7	1·9	2·0	1·5	1·4
Radials height	1·25	1·1	1·1	1·2	1·4	3·4	3·2	3·8	2·8	2·9	2·9	3·1	3·2	2·2	2·3
Radials lower breadth (A)	0·8	0·75	0·75	0·9	0·9	2·7	2·75	2·8	2·3	2·1	2·1	2·3	2·7	1·7	1·6
Radials upper breadth (B)	2·25	2·1	2·4	2·25	2·6	5·9	5·9	6·2	5·8	5·4	5·3	5·3	6·4	4·4	4·0
A as % B	35	36	31	40	35	46	47	45	40	39	39	43	42	39	41
POST-RADIAL SERIES :															
Crown 1 (incl. Rs)	22	22	34	30	27	68	..	..	..	..	..	..	..	..	..
IBr_1 and $_2$ length	2·75	2·5	3·2	2·8	2·95	4·8	4·9	5·3	4·9	5·2	4·5	5·0	5·2	6·1	5·6
IBr_{1+2} breadth	1·6	1·7	1·5	2·0	1·75	2·75	2·7	2·9	2·5	2·3	2·5	2·4	2·7	3·5	2·9
IBr_1–Br_4 length	5·4	5·5	6·7	6·0	6·0	9·2	9·2	11·2	8·8	9·6	9·3	9·2	10·2	11·7	10·0
Br_{4+5} breadth	0·6	0·7	0·7	0·75	0·75	2·1	1·8	2·2	1·8	1·6	2·1	1·9	2·3	2·1	1·4
Brachial with 1st pinnule	10(11)	10(11)	8, 9	(8)9(10)	(9)10(11)	8	8	(7)8, 9	8	7, 8	8	8	..	12(11)	11

1, 2 *B. gracilis* : *Chain* st. 328. 3–5 *B. aldrichianus* : 3 holotype, 4, 5 *Atlantis II* st. 259. 6–14 *B. australis* : 6–12 *Atlantis II* st. 247B, 13 *Atlantis II* st. 247A, 14 *Atlantis II* st. 245, 15 *Challenger* st. 146, syntype. Discoidal columnals have height not more than 1/6 breadth. Maximum heights or breadths are given unless otherwise stated; division series lengths are measured to the middle of the joint with the radial. 'Br' signifies brachial. Measurements in mm.

between there and the Azores and off the Cape Verde Islands. Bathymetric distribution 3317–5600 metres.

Bathycrinus australis A. H. Clark

Bathycrinus aldrichianus: P. H. Carpenter, 1884 : 241–243, pl. 7, pl. 7a, figs 1–21, pl. 7b, pl. 8a, figs 4, 5 ; Gislén, 1928 : 14. [Non *B. aldrichianus* Wyville Thomson, 1876.]
Bathycrinus australis A. H. Clark, 1907 : 553–554 ; Döderlein, 1912 : 9–10, pl. 5, fig. 1, pl. 6, fig. 7 ; Gislén, 1938 : 16 ; 1956 : 61–62, pl. 1, figs 1–6.
Ilycrinus australis: A. H. Clark, 1915b : 154–155.

Material. *Challenger* st. 146, 46°16′S, 48°27′E (W. of the Crozet Islands, Southern Ocean), 2515 metres ; 2 syntypes, BM(NH) reg. no. 85.2.30.3, 4.

Atlantis II cruise 60, st. 245A & B, 36°55·7′S, 53°01·4′W (off Rio de la Plata, Argentina), 2707 metres ; 1 specimen lacking most of stalk, 1 crown and a length of stalk.

Atlantis II cruise 60, st. 247A & B, 43°33′S, 48°58·1′W, 5208–5223 metres, 8 specimens with stalk and arms more or less incomplete, 19 crowns, 2 lengths of stalk.

Some numerical data from the more nearly intact of these specimens is given in Table 1. No *Atlantis II* specimens retain the distal end of the stalk. The syntypes retain stumps of the main branches, as shown in Carpenter's pl. 7 (1884) and Gislén's pl. 1 (1956) with stout cylindrical segments and no radicular cirri arising above the main dichotomy. One syntype has several successive very short (but not quite discoidal) columnals just above the dichotomy. The form of 'rooting' is similar to that in the northern species *Bathycrinus carpenteri* (Danielssen & Koren).

The longest detached piece of stalk measures *c.* 100 mm and has 44 columnals, the uppermost ones short but not discoidal so that the break probably came between the fifteenth and twentieth segments. The breadth at the top is 1·6 mm. As the columnals elongate distally they also become slightly constricted medially (a dice-box-shape according to Carpenter). The longest columnal measures 3·3/1·7 mm length/median breadth (1·9/1) with the maximum breadth at the joints up to 2·0 mm. A more distal piece of another stalk 80 mm long with 37 columnals, similar to the first in the proportions of its middle segments, has the distalmost columnals remaining (probably to close above the main division) much stouter and shorter, the measurements 2·75/2·2/3·0 mm ; their successive joints are 'screwed'.

Gislén (1956) gives the proportions of the longer columnals in a detached piece of stalk as 3/0·8/1 mm, which is relatively longer than in these specimens. In the syntype measured the columnals are also relatively slender with length/median breadth up to 2·7/1.

Specimen 14 in Table 1 from st. 245 is somewhat smaller than those from the more southern station 247 as regards the stalk and calyx but has relatively large division series. This is also true of the broken crown from st. 245, where the division series are *c.* 6·0 mm long at a radial height of only 1·8 mm and upper breadth of 4·8 mm. Another difference in the first specimen is the more numerous discoidal proximal columnals, about 18 as opposed to 9–13, with the first columnal to be higher than broad not until about the thirty-fifth, rather than about the twenty-seventh.

There is also one much smaller crown from st. 247 with the height of the radials only 1·35 mm (as opposed to 2·8–3·8 mm in the others from that station measured). The lower and upper breadths of its radial ring are 0·7 and 1·9 mm, so the height is relatively greater in comparison with the larger specimens, 71% of the upper breadth as opposed to 48–61% (mean 55%). This small specimen, like the syntypes, also differs in having the lateral flange on the division series and proximal brachials (in this case restricted to the first four or five) relatively thin and the arms are markedly convex medially, from Br_5 with a blunt keel. The larger specimens have the arms almost flat on top proximally, though beyond the bases they become somewhat compressed laterally. Their lateral flanges are blunter and extend as far as about Br_{11}. As usual, syzygies in the small specimen are proximally at 1+2, 4+5 and 7+8; all are broken by Br_{10}. Two arms at least have the first pinnule (P_b) on Br_6; on the other arms it is P_3 on Br_8 (as in the larger specimens from this station) and measures 6·5–7·0 mm in length. Only the specimen from st. 245 agrees with the syntypes in having the first pinnule usually on Br_{11} or $_{12}$. According to Gislén (1956) pinnules begin distal to Br_{11} in his material from the Kermadec Trench.

An intact arm of specimen 6 in the table is 60 mm long and has 108 brachials. The frequency of syzygies on this arm decreases distally so that beyond *c.* Br_{40} only one out of every five joints is usually a syzygy. This compares with *B. aldrichianus* where syzygies tend to alternate with muscular joints throughout the arm beyond the base.

A broken calyx shows four vertical cracks in the basal ring, of which three correspond to the interbasal (BB) sutures; these are otherwise not distinct.

The suture between the basal ring and the uppermost columnal is indistinct in all the specimens. Only in the syntype shown in Carpenter's pl. 7, fig. 2 is the basal ring so abruptly marked off from the radial ring by slightly swollen contours adjoining the suture; otherwise the transition is fairly smooth.

Affinities. This relatively large and smooth species of *Bathycrinus* closely resembles *B. carpenteri* (Danielssen & Koren) from the deep basin of the Norwegian Sea (see A. M. Clark, 1970), though considerably exceeding the northern species in size – the largest *B. carpenteri* described having crowns up to *c.* 35 mm in length, compared with nearly 70 mm in the present material. The division series and proximal parts of the arms in *B. carpenteri* are more convex but this may be correlated with the smaller size.

Bathycrinus australocrucis McKnight (1973) from New Zealand is another relatively smooth species, but has median keels on the arms from Br_4 and beyond the arm bases these are flared distally so as to produce a serrated profile, though much less so than in *B. aldrichianus*. It also differs in the fewer short proximal columnals, of which the twelfth is already longer than broad. The crown in the holotype is probably about 20 mm long.

B. australis, with its flared radial ring, also has some resemblance to *Zeuctocrinus*, from the North Atlantic, which I described and referred to the Phrynocrinidae in 1973, particularly to the young specimen shown in fig. 5c (Clark, 1973) where the uppermost columnals are discoidal, unlike the condition in larger specimens. Phrynocrinids have the calyx more integrated and compact and the bases of the division

series are well separated laterally. In addition their stalk attachment is by an expanded disc.

DISTRIBUTION. The present records extend the range of *B. australis* to the deep Argentinian plateau of the SW. Atlantic. The other records are widely scattered around the southern hemisphere from the vicinity of the Crozet Islands (*c.* 46°S, 48°E – the type locality), off Enderby Land, Antarctica (*c.* 63°S, 58°E) and around New Zealand (*c.* 35°S, 179°W and 38°S, 171°E). The depth range is 1748 (?1730) – 8210 (?8300) metres.

Bathycrinus carpenteri (Danielssen & Koren)

Ilycrinus carpenteri Danielssen & Koren, 1877 : 45–56, pls 1, 2.
Bathycrinus carpenteri : Danielssen, 1892 : 1–28, 5 pls ; A. M. Clark, 1970 : 14–18, fig. 3.
Bathycrinus carpenterii : Gislén, 1938 : 16–17.

TYPE DESIGNATION. Due to incorrect labelling as 'Types' of two specimens in the Oslo Museum collection from Norwegian North-Atlantic Expedition st. 295, my citation of these as syntypes (1970 : 14) has to be emended. Dr Holthuis has pointed out to Dr Marit Christiansen of the Oslo Museum that this sample dates from 1878 and only material from N.N.E. stations 35, 40, 51 and 53 was available to Danielssen & Koren in 1877. Since that paper was in Norwegian I had relied upon Danielssen's of 1892 with its English translation.

Although the entire holdings of crinoids in the Oslo, Bergen, Trondheim and Tromsø Museums were sent to me (as I understand), from these four stations only the crown and stalk from st. 35, Bergen Museum no. 1159, were included, so that the fate of the best eligible specimen for selection as lectotype, from st. 51 is unknown. The other material from these early stations consisted of stalks or broken specimens. I therefore designate as lectotype the crown and stalk from st. 35, 63°22′N, 1°20′W (between Norway and Iceland, NE. from the Faeroes), 1920 metres, in the Bergen Museum.

Bathycrinus gracilis Wyville Thomson

(Fig. 1a–f)

Bathycrinus gracilis Wyville Thomson, 1872 : 772–773 ; 1873 : 450–454, fig. 73 ; P. H. Carpenter, 1884 : 243–245, fig. 16, pl. 8a, figs 1–3 ; Koehler, 1909 : 254 ; Gislén, 1938 : 18.

MATERIAL. *Chain* cruise 106, st. 328, 50°04·7′N, 15°44·8′W (*c.* 200 miles (320 km) WSW. of Cape Clear, SW. Ireland), 4426–4435 metres ; 2 crowns, 1 calyx with costals and proximal part of stalk, 3 juveniles, 8 pentacrinoids.

Porcupine 1869, st. 37, 47°38′N, 12°08′W (*c.* 200 miles (320 km) S. of Cape Clear), 4450 metres ; incomplete paratype, BM(NH) reg. no. 85.3.30.33.

Only three specimens of this, the type species of *Bathycrinus*, have so far been recorded (Perrier's from off Morocco having been referred to a distinct species, *B. perrieri*, by Koehler & Vaney in 1910). According to Carpenter (1884), the immature holotype had the whole crown only 8 mm high with just 12 brachials and only rudiments of pinnules developing at the tips. Unfortunately its whereabouts

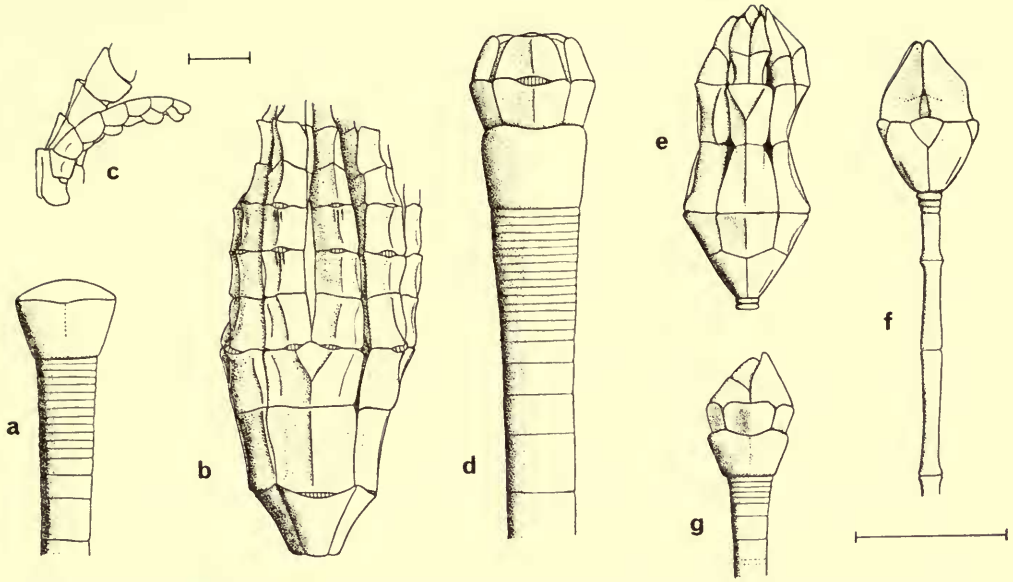

FIG. 1. a–f. *Bathycrinus gracilis* Wyville Thomson. a. Paratype, basal ring and proximal end of stalk [badly decalcified]. b–f. *Chain* st. 328. b. Crown. c. Detail of pinnule. d. Specimen broken after first post-radial ossicle (IBr_1), which itself with the radials is probably incompletely regenerated. e. Very young specimen with 'integrated' calyx and only two brachials of each arm yet developed. f. Pentacrinoid at 'cystoid' stage with rudimentary radials not yet obscuring the oral plates. g. *Bathycrinus aldrichianus* Wyville Thomson. *Chain* st. 85, juvenile specimen apparently broken above the radials revealing the orals. All viewed radially. [The scales measure 1 mm ; the small one applies to b and c and the large one to the remainder.]

are unknown. A crownless paratype in the British Museum collection consists of *c.* 60 mm length of stalk topped by the basal ring ; it is now badly decalcified and broken into three pieces. Both specimens were taken at a single *Porcupine* station *c.* 200 miles (320 km) S. of Cape Clear, SW. Ireland. The third known specimen, a stalkless crown only slightly larger than the holotype, measuring 11 mm, was collected by the *Princesse Alice* between the Azores and Portugal and was described by Koehler (1909) simply as conforming with the holotype.

The paratype (Fig. 1a) has the upper side of the basal ring slightly domed ; the height of the exposed part is 0·35 mm, the maximum (upper) diameter 0·60 mm and the lower diameter 0·45 mm. The individual basals are slightly convex above and faint interbasal sutures can just be discerned when partially dried. The top 13 columnals can be described as discoidal (i.e. with l/br less than 1/6). The stalk diameter tapers to a minimum of 0·3 mm at about the fifteenth columnal. The seventeenth is the first with length exceeding breadth and the following columnals become very attenuated, up to 3 mm long, with l/median br *c.* 6/1 and the joints markedly broadened, the successive ones elliptical in almost alternating planes. The columnals have a very fine fingerprint-like texture of fine longitudinal grooves, while the basal ring appears superficially granular but these effects are likely to be

inherent in the plate structure and a reflection only of the considerable magnification used, and as such probably without taxonomic significance.

The two crowns taken by the *Chain* probably had slightly larger basal rings since the lower diameter of the radial ring is 0·75 and 0·80 mm. Some measurements of them are given in Table 1. One specimen (Fig. 1b) has the radials distinctly concave in profile, whereas in the other they are straight. The individual radials are convex in cross-section but not keeled ; their surface is finely 'fingerprinted' with longitudinal grooves. This texture is not continued on the division series which have a sharp median hyaline crest and thin, sharp-edged lateral flanges. On the IBr_2 (axillary) the median crest is Y-shaped, matching up distally with the crests on the proximal brachials. From about Br_3 additional crests appear at the distal end of each brachial beside the median one, producing a fluted median area. The distal ends of the brachials from Br_2 onwards are more or less flared so as to make the profile distinctly serrated. Lateral flanges extend on the arms to *c.* Br_{10}. Syzygies are present at 1+2, 4+5, 7+8, 10+11 and then alternately (i.e. only brachials 3, 6 and often also 9 have muscular joints at both ends). The first pinnule, P_c, is on Br_{10} (or Br_{11}). The gonads are visible by transparency. The longer pinnules have six or sometimes seven segments.

Clearly *Bathycrinus gracilis* shares the vulnerability of the calyx to break above the basal ring shown by other species of the genus. Regeneration of the crown is probably common and seems to have occurred in the specimen with the stalk and basal ring (Fig. 1d) since its radials are abnormally small and their lower ends are inset so that the diameter of the lower end of the radial ring is less than that of the upper end of the basal ring (0·65 mm). The basals lower diameter is 0·60 mm and the height 0·55 mm, so the relative height is greater but the expansion of the top of the ring less than in the paratype. No interbasal sutures can be seen. The maximum upper diameter of the radial ring is only 0·85 mm and above this only one ossicle, the IBr_1, remains in each radius ; these costals are relatively short and are spaced laterally. Both radials and costals have a sharp median crest. The basal ring has a granular texture but the radials show a suggestion of 'fingerprinting'. The diameter at the top of the stalk is 0·60 mm (compared with 0·45 mm in the paratype) and there are 16 discoidal proximal columnals. The first columnal to be longer than broad is the twenty-first. The stalk diameter reduces to 0·45 mm at *c.* 10 mm from the top. The succeeding columnals become very elongated with l/med. br *c.* 2·0/0·35 mm (5·5/1). The joints are expanded elliptically in almost alternating planes. Columnals 21–29 have a slightly projecting median belt around them. The stalk is broken at the forty-fifth columnal and the total length measures 42 mm ; at a thickness of less then 0·5 mm the whole specimen is thread-like.

It is to be expected that very young specimens of *Bathycrinus* would have the individual basals still separate, as in the related genus *Monachocrinus*, which is neotenous in this respect. This theory is borne out by two little specimens from the same *Chain* station with only two brachials on each arm yet developed (Fig. 1e). In these the basal and radial rings are integrated into a cone and all the sutures between them are distinct. The radials are distinguished by their hyaline median crest-like keels matching those on the division series and first brachials. Unfortunately only

a few discoidal proximal columnals remain attached to both these specimens. There are also present several smaller ones which may be classed as pentacrinoid larvae in the 'cystoid' stage, with radials undeveloped and the orals (of similar size to the basals) exposed. Yet other specimens have narrow radials and laterally separated post-radial series developing.

Also included in this sample is a relatively large very zig-zag segmented fragment of the distal end of a stalk, with radicular cirri branching off it, often at acute reflexed angles. This resembles the stalk attachments of *Bathycrinus nodipes* Döderlein, from the East Indies (1907, pl. 5, figs 2, 3) and the size is commensurate with the two crowns, to one of which it presumably belonged ; sadly the intervening column and basal ring are missing.

The other Atlantic species of *Bathycrinus* currently recognized are *B. carpenteri* (Danielssen & Koren) from the deep basin of the Norwegian Sea and *B. aldrichianus* Wyville Thomson recorded from the Gulf of Guinea, equatorial mid-Atlantic and east of the U.S.A. (*B. perrieri* Koehler & Vaney having been referred to *Monachocrinus* since it has the interbasal sutures distinct). In addition, the present collection extends the range of *B. australis* A. H. Clark, previously known from various localities in the Southern Ocean and South Pacific, to the South Atlantic off Argentina. Both *B. carpenteri* and *B. australis* have notably smooth rounded ossicles and profiles but *B. aldrichianus* resembles these two crowns of *B. gracilis* in being similarly very serrated in profile. However, the holotype of *B. aldrichianus* has the median parts of the ossicles more rounded, except on the middle part of each division series where the convexity is constricted to a narrow median blunt ridge. Gislén (1951) described a crown of *B. aldrichianus* as much as 56 mm long from off the Cape Verde Islands in which the division series have a 'rounded, narrow and indistinct median dorsal ridge'. It is possible that the sharpness of the crests in *B. gracilis* is correlated with the relatively small size.

Distribution. SW. of Ireland to NE. of the Azores (*c.* 39°N, 21°W), 4435 (?4426) – 5005 metres.

Democrinus Perrier

Democrinus Perrier, 1883 : 450 ; A. H. Clark, 1917 : 392 ; Gislén, 1938 : 25. Type species *D. parfaiti* Perrier, 1883.
Rhizocrinus (pt) : Carpenter, 1884 : 245 ; A. H. Clark, 1909 : 673–676.
Rhizocrinus (*Bythocrinus*) Döderlein, 1912 : 11 [No type designated for subgenus.]
Bythocrinus : A. H. Clark, 1917 : 392.

Seven nominal species of five-armed Atlantic bathycrinids with at least the interbasal sutures of the calyx distinguishable have been referred to *Democrinus*, namely :

Democrinus parfaiti Perrier, 1883, from Morocco
Rhizocrinus rawsoni Pourtalès, 1874, Barbados
R. conifer A. H. Clark, 1909, Brazil
R. brevis A. H. Clark, 1909, Atlantic side of Panama [and ? Leeward Is]
R. sabae A. H. Clark, 1909, Leeward Is

R. robustus A. H. Clark, 1909, W. of Florida
Bythocrinus intermedius A. H. Clark, 1915(a), Gulf of Mexico

The first two were treated as synonymous by Carpenter (1884) but *D. parfaiti* was revived by A. H. Clark (1909) when he named and partially described four other related nominal species. Of these, Gislén (1938) referred *R. sabae* to the synonymy of *D. rawsoni* and *R. robustus* to the synonymy of *D. conifer*, adding to the latter (at A. H. Clark's own suggestion) also *B. intermedius* (a name based only on a drawing of part of the stalk and a locality given in the caption to this). The calyx of *D. conifer* was figured by A. H. Clark (1915a) and those of the holotype and a paratype of *D. brevis* had been given by Carpenter (1884) but no representations of the calyces of *R. sabae*, *R. robustus* or *B. intermedius* are extant. A. H. Clark's (1909) descriptions of the first two are hardly explicit but diagrammatic reconstructions as shown in Fig. 2e and f can be made from them. The resultant shapes support Gislén's conclusions. Following study of a new sample of *D. parfaiti*, described below, I think that calyx shape may be used as a specific character for some species of *Democrinus*, provided the growth stage is taken into consideration. This sample also includes distal ends of some stalks showing a slender branching root-like form of cylindrical radicular cirri (Fig. 3b), as in *Bathycrinus carpenteri* (Danielssen & Koren). This contrasts with the attachment found in *D. brevis* (Fig. 2d) by an expanded, irregularly lobed plate more or less appressed to and fused with the substrate, there being only a few radicular cirri arising from the lower columnals. In 1973 I established a new family Porphyrocrinidae for *Porphyrocrinus* Gislén and *Naumachocrinus* A. H. Clark, which resemble bathycrinids in most respects but are attached by a simple expansion of the distal end of the stalk moulded to a solid piece of substrate. The attachment in *Democrinus brevis* and probably also in *D. rawsoni* appears transitional to this and casts doubt on the one hand on the wisdom of making a family distinction on this character alone and on the other of regarding *D. brevis* and *D. rawsoni* as congeneric with *D. parfaiti*. Knowledge of the stalk attachments of a wider range of species of bathycrinids than we now have is needed to settle this problem.

Unfortunately, from the above list material only of *D. parfaiti* and *D. brevis* is available to me at present and a revision of the Atlantic *Democrinus* specimens in the U.S. National Museum is badly needed, particularly the types of *D. rawsoni*, about which only some comments derived from Pourtalès (1874) can now be given.

Democrinus brevis (A. H. Clark)

(Fig. 2a–d)

Rhizocrinus rawsoni: Carpenter, 1884 (pt) : 263 (*Investigator* records), 266–267, fig. 19; A. Agassiz, 1892 : 62 (footnote).
Rhizocrinus brevis A. H. Clark, 1909 : 675.
Bythocrinus brevis: A. H. Clark, 1917 : 392.
Democrinus rawsoni: Gislén, 1928 : 14–15.
Democrinus brevis: Gislén, 1938 : 26.

MATERIAL. *Investigator*, Capt. Cole: 'Off Colon' [altered by Bell from 'off Panama' following query by Agassiz], '15 miles N. by E. of Panama [i.e. Colon on

the Atlantic side], 'Saba Bank, 15 miles N. by E. of Panama' and 'Saba Bank, Panama', 550 metres ; 4 specimens, BM(NH) reg. nos 84.6.20.8 and 9, 1935.3.15.1 and 1949.4.5.1. The two last specimens were transferred to the Zoology Department from the Geology Department about 1935 but one was put on exhibit until 1948. Carpenter cited the *Investigator* records as 'Saba Bank, 200 fathoms. 15 miles N. by E. of Panama, 300 fathoms' but the two appear to have been confused in labelling and relabelling the last two specimens. I can find no Saba Bank in the vicinity of Colon and it must presumably refer to the one in the Leeward Islands near St Kitts. The first specimen is the one shown in Carpenter's fig. 19A and was designated as (holo)type by A. H. Clark ; the rest may be treated as paratypes since all four were evidently studied by him.

Cuba (no details), M. H. Gray ; 8 specimens, no. 1900.5.17.1–3.

Description. Some numerical details of these specimens are given in Table 2.

The holotype is badly broken. Four columnals are still attached to the calyx ; the uppermost one only is discoidal, the length increasing so that the fourth is longer than broad (Carpenter's figure being incorrect in showing two non-existent discoidal columnals in place of the lower end of the basals below the constriction in the calyx). The arms also have broken off, mostly at the 3+4 syzygy. They are slightly reduced in size beyond the first brachial (Br_1) and may have incompletely regenerated. The detached distal end of the stalk is still present with three very squat 'screwed' columnals above a flared expansion of branching irregular lobes attached to a piece of black substrate resembling solidified mud with a fibrous backing. Two cylindrical radicular cirri appear to have broken off from one side of the upper end of the distalmost columnal. Two parts of the stalk contribute to a total of only 38 columnals so there are probably other parts missing. The calyx (Fig. 2a) expands fairly abruptly between a quarter and a third of its height above the topmost columnal and there is a second but lesser expansion in the radials, so as to create a slight hollowing in the vicinity of the basiradial (BR) suture, which forms a very shallow zig-zag around the calyx and is clearly distinguishable, as are the interbasal (BB) and interradial (RR) sutures.

The paratype, no. 84.6.20.9, is in much better condition, though the distal end of the stalk is lost. As Carpenter's fig. 19B shows, the calyx is more evenly conical than in the holotype. Also the proximal brachials are rather irregular, some ossicles being unnaturally long, possibly fused, and others apparently subdivided. There may also be two successive muscular or syzygial joints instead of the normal alternation of joints that occurs for the rest of the arms. The position of the first pinnule is also, perhaps consequently, rather irregular. One arm has a pinnule on *both* sides of Br_8, another on both sides of Br_9 ; otherwise it is unduplicated and twice on Br_7 and once on Br_8. A complete arm measures 80 mm and has 113 brachials, with about 26 pinnules each side. A proximal pinnule has 16 segments and measures *c.* 7·5 mm in length. The first six brachials have sharp lateral flanges after which the arm becomes constricted laterally.

No. 1935.3.15.1 again has retained a detached distal end of the stalk with lobed extensions fused to the substrate. The calyx is regularly conical except for a slight hollowing near the BR suture. The sutures are less distinct than in the other

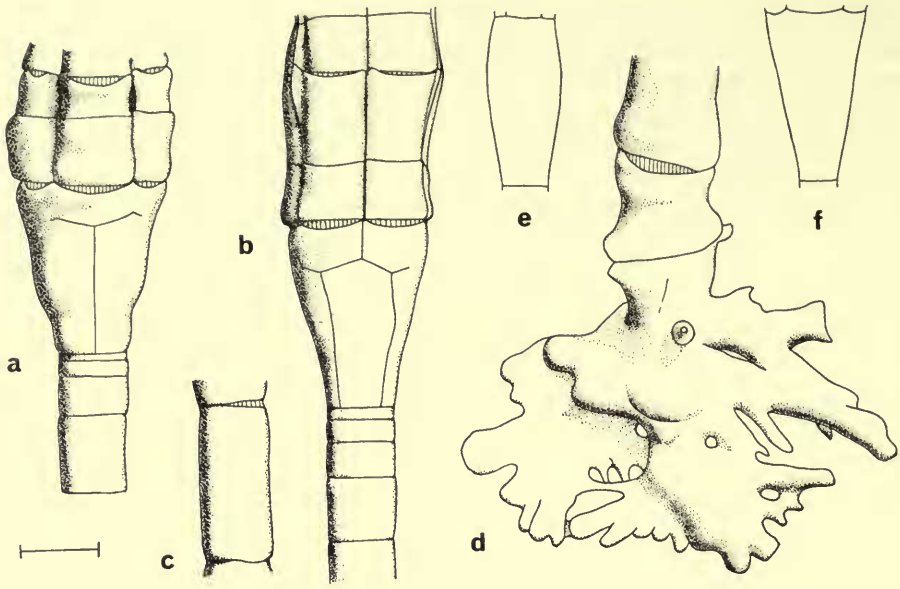

FIG. 2. a–d. *Democrinus brevis* (A. H. Clark). a. Holotype, calyx and adjacent ossicles viewed radially. b–d. B.M. no. 1900.5.17.1, Cuba. b. Calyx and adjacent ossicles viewed interradially. c. Tenth columnal. d. Distal end of stalk (attached substrate omitted). e and f. Reconstructions from descriptions and measurements of holotypes of *Rhizocrinus sabae* A. H. Clark and *R. robustus* A. H. Clark, synonymized by Gislén with *Democrinus rawsoni* and *D. conifer* respectively. [The scale measures *c.* 2 mm.]

specimens (but still more easily seen than those of *Democrinus parfaiti*). The arms have become detached at the first joint but remain in a group ; the first pinnule is on Br_9, Br_{10} or Br_{12} on three arms, has not yet appeared by the last remaining brachial, Br_{13}, on the fourth, while the last arm is broken earlier. Lateral flanges extend to Br_7.

The last paratype, 1949.4.5.1, is badly broken. The top four columnals are abnormal in all being discoidal, not gradually increasing in length, so that it is not until the seventh that the length exceeds the breadth. Only the bases of three arms remain attached to the calyx.

Carpenter (1884) gave the maximum length of these specimens (presumably including the arms) as 190 mm with arm length 75 mm, making a stalk and calyx length of 115 mm. This approximates to my measurements of the first paratype, lacking the distal end of the stalk.

The specimens from Cuba also show irregular distal expansions of the stalk (Fig. 2d) attached to pieces of the substrate, with relatively few radicular cirri arising from the distalmost columnals. The arms, or parts of them, are present in five individuals and are broad for about the first five brachials. The calyx is distinctly conical, sometimes with a small angle in the profile of the lower half if the broadening increases abruptly and usually a slight hollowing around the BR suture.

TABLE 2

Numerical data from specimens of *Democrinus brevis* (A. H. Clark) and *D. parfaiti* Perrier in the British Museum collections.

	Stalk							Calyx			
	Length	No. of columnals	Distal breadth (maximum)	Proximal breadth	Longest columnal length	1/med. br.	1st col. 1 > br.	Height (maximum)	Breadth (maximum)	Br. as % of ht.	Basals height
Democrinus brevis											
Holotype	..	..	2·50	1·50	4·42	2·6/1	4	4·00	3·25	81	3·25
Paratypes	120	45–*c.* 50	*c.* 2·6	1·4–1·7	3·0–3·8	2·2–2·6	3–5 (7)	3·1–3·5	2·9–3·5	85–100	2·5–2·7
Cuban specimens	150–210	45–55	2·2–2·8	1·5–1·8	3·3–4·8	2·1–2·7	(3) 4,5	4·0–5·6	3·0–3·9	64–83	3·2–4·6
Aberrant Cuban	210+	55+	3·0	1·5	4·9	3·3	6	4·6	3·0	65	3·8
Democrinus parfaiti											
Smallest	70	41	1·2	1·1	2·4	3·2	5	2·5	1·5	60	..
Largest	140++	58++	..	1·3	2·7	2·1	3	7·7	2·8	36	..
Remainder	70–190+	39–67	1·2–2·5	1·2–1·6	2·2–3·5	1·6–2·4	3,4 (5)	3·3–6·2	1·7–3·2	44–62	..

The length of the stalk and the number of columnals in it are taken only to the first major division at the distal end; the maximum breadth is measured across the most expanded joint, while the proximal breadth is taken across the topmost columnal and normally coincides with the minimum breadth as well as with the breadth of the bottom of the calyx. Because of the indistinct sutures the height of the basals was not measured in *D. parfaiti*. Measurements in mm.

Again there is no sign of any sudden constriction near the top of the calyx, unlike *D. parfaiti*. The sutures are relatively easily distinguished and mostly fairly straight, though the long BB ones may be partially sinuous (Fig. 2b).

Like three of the types of *D. brevis*, these Cuban specimens were hitherto labelled as *Democrinus rawsoni*, under which name Gislén (1928) discussed them, treating the two lots as conspecific. Although the calyx is more squat in the types (maximum breadth 81–100% of the height, compared with 64–83% in the Cuban specimens), the similarity in stalk attachment, shape and proportions of columnals* and arms and conical form of the calyx, is so marked that I must agree with Gislén.

It remains to be determined whether *D. brevis* is specifically distinct from *D. rawsoni*, the type material of which evidently has the calyx much more nearly cylindrical in shape, at a comparable height, and not broadest at the top of the radial ring, unlike the specimens just discussed. The consistency of form of the calyx in the sample of 24 specimens of *D. parfaiti* discussed below indicates that the shape does provide a specific character in some cases, though it must be considered in the light of growth changes. Gislén (1927) has demonstrated that growth in the calyx of his *Democrinus japonicus* changes the shape from conical in the young to almost cylindrical in the larger specimens and I have also found this to be true in *Democrinus chuni* (Döderlein) in south-east Africa (1972 : 146–150). In *D. parfaiti* too, growth of the calyx is stronger vertically than horizontally. However, it is perhaps not impossible that in *D. rawsoni* the growth gradients are reversed or much more variable. Until more precise details are available this problem must go unsolved.

Distribution. Atlantic side of Panama ; northern Leeward Islands ; Cuba ; 360–550 metres.

Democrinus parfaiti Perrier

(Fig. 3)

Democrinus parfaiti Perrier, 1883 : 450–451 ; 1886 : fig. 192 ; A. H. Clark, 1923 : 46 ; Mortensen, 1927 : 20, fig. 8 ; Gislén, 1938 : 28–29 ; 1947 : 7–9, fig. 3 ; A. H. Clark, 1949 : 376 ; Gislén, 1951 : 56, 57.

Rhizocrinus rawsoni : Carpenter, 1884 (pt) : 263, 265, 268, ? pl. 9, figs 3–5, pl. 10, figs 3–5 and 8–14 only, ? pl. 53, figs 7, 8 ; Koehler, 1909 : 255–256 ; Koehler & Vaney, 1910 : 31 ; Döderlein, 1912 : 12–13, fig. 4, pl. 4, fig. 7, pl. 9, fig. 2. Non *R. rawsoni* Pourtalès, 1874].

Rhizocrinus parfaiti : A. H. Clark, 1909 : 676.

Material. *Shackleton* cruise 3, 1973 : st. 152, 36°35·7′N, 11°04·1′W–36°37·2′N, 11°05·3′W, Ormonde Sea Mount (SW. from Cape St Vincent, Portugal), 2292–1691 metres, muddy ; 5 specimens. St. 153, 36°39·0N, 11°07·9′W–36°39·7′N, 11°08·1′W, 871–650 metres ; 1 specimen. St. 154, 36°33·8′N, 11°06·5′W–36°35·4′N, 11°06·9′W, 2959–1946 metres, limestone and mud ; 2 specimens. St. 175, 36°20·9′N, 12°53·3′W –36°22·8′N, 12°53·1′W, 3010–2210 metres, rocky and mud gravel ; 14 specimens.

* As Gislén noted, one Cuban specimen – the aberrant one in Table 2 – has relatively longer columnals than the others, length/median breadth up to 3·3/1, otherwise not more than 2·7/1. It has the longest stalk, 210 mm plus *c.* 5 mm since a few of the distalmost columnals are lost. Even so, the maximum distal breadth is as much as 3·0 mm. In other respects it agrees with the remaining seven specimens and I think they are conspecific.

St. 176, 36°26·4'N, 12°55·8'W–36°27·6'N, 12°56·0'W, Cromer Sea Mount, 1143–1130 metres, muddy; 2 specimens. BM(NH) reg. nos 1976.1.12.3–5, 6, 7, 8–20 and 21.

Challenger st. 76, 38°11'N, 27°09'W (S. of Terceira, Azores), 1645 metres; 2 specimens, no. 85.3.30.1.

Porcupine st. 43, 1869, 50°01'N, 12°26'W (off Cape Clear, SW. Ireland), 2210 metres, globigerina ooze; 2 young specimens, no. 85.3.30.2.

Nomenclature. Only a year after being first described, *Democrinus parfaiti* from Morocco was referred by Carpenter (1884) to the synonymy of *Rhizocrinus rawsoni* Pourtalès, 1874, type locality off Barbados. In 1909 A. H. Clark restored it to specific rank, at the same time describing no less than four nominal species of *Rhizocrinus* from the western Atlantic, one of them, *R. brevis*, split off from *R. rawsoni* sensu Carpenter. In 1917 A. H. Clark revived the genus *Democrinus* for the species previously referred to *Rhizocrinus* with distinct sutures within the calyx, unlike the type species, *Rhizocrinus lofotensis* M. Sars. This treatment was followed by Mortensen and Gislén. In 1947 Gislén published drawings by Cherbonnier of the calyces of two of Perrier's *Travailleur* (syn)types from Morocco, with correct measurements, unlike the misleading ones given by Perrier to Carpenter. However, *D. parfaiti* has never been adequately described and information about the growth changes and variation is needed for comparison with the other Atlantic species of the genus.

Description. In 12 specimens with the distalmost columnals preserved, the stalk terminates in an abrupt division into two or three major branches of similar magnitude, which themselves divide further into a number of radicular cirri with long, slender, cylindrical segments, forming an extensive ramifying root system similar to that in *Bathycrinus*. On one well-preserved stalk *c.* 100 mm long the total length of the 'rooted' portion exceeds 35 mm. Sometimes there may be some additional small radicular cirri arising near the ends of several of the distalmost columnals.

These lower columnals are 'screwed', that is elliptical at the joints but twisted so that the successive joints have their long axes almost at right angles, facilitating multi-directional flexure. Unlike the squat distalmost columnals of *Democrinus brevis*, in this species they are appreciably longer than the maximum breadth. After about the ten lowest ossicles, the following ones become more nearly round in cross-section throughout their length and are less constricted medially, sometimes almost perfectly cylindrical and, in larger specimens, the more proximal ones may be slightly barrel shaped. They retain about the same length until close below the calyx, where the length rapidly decreases so that the third or fourth columnal from the top is the last to be longer than broad, except in two specimens (including the smallest one) where it is the fifth. The stalk length to the main distal division ranges from 70 to *c.* 200 mm and the number of columnals from 39 to at least 67.

The calyx is relatively high and narrow and in every case has a more or less deep constriction near its upper end, which is emphasized by shrinkage of the thickened integument when specimens are dried. As noted by Carpenter, the constriction does

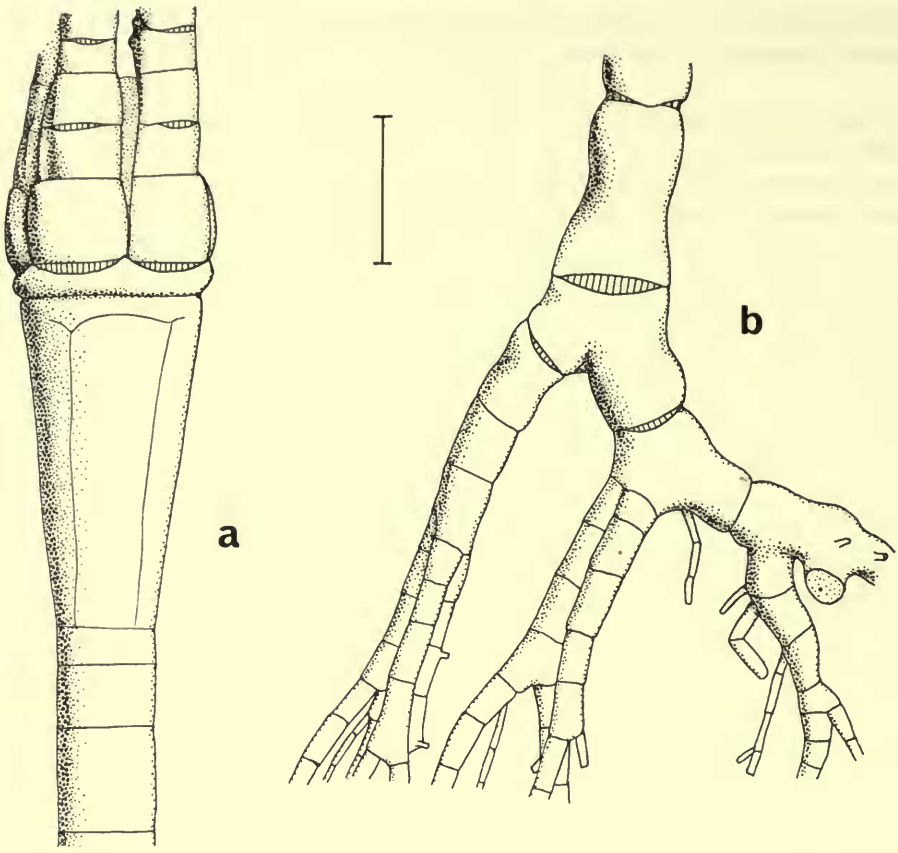

FIG. 3. *Democrinus parfaiti* Perrier. a. *Shackleton* st. 175, calyx and adjacent ossicles viewed interradially. b. st. 152, distal end of stalk with 'roots'. [The scale measures 2 mm.]

not coincide with the basiradial (BR) suture but 'crosses the radials at the level of the highest angles of the basals' as shown in a drawing sent to him by Perrier and as he observed himself in one of the small *Porcupine* specimens (1884, pl. 53, fig. 8). However, Carpenter's artist incorrectly drew the BB suture as extending right up to the constriction in a *Challenger* Azores specimen (pl. 10, fig. 3), an impression also given by Cherbonnier's drawings of two syntypes (in Gislén, 1947, fig. 3), he having probably been misled by Perrier's description of the constriction separating the basals and radials. Certainly the upper end of this suture is usually very faint. In some of the *Shackleton* specimens even the upper interradial angles of the basals come below the constriction (Fig. 3a) which falls entirely within the radials, as shown in a type of *D. conifer* by A. H. Clark (1915a, fig. 131) and in a Caribbean specimen by Carpenter (1884, pl. 9, fig. 3). Below the constriction the calyx is almost cylindrical or narrowly conical, with a slight increase in the degree of taper in the lower half. The diameter at the lower end is as much as 69% of the maximum diameter across the radials,

decreasing to *c.* 45% in the largest few specimens (calyx height >6 mm), the mean over the whole size range being 54%. The shape of the calyx is therefore not more openly conical in younger specimens in contrast to *Democrinus chuni* (Döderlein) and *D. japonicus* Gislén (see A. M. Clark, 1972 and Gislén, 1927). The sutures in the calyx are very indistinct ; though the interbasal (BB) ones can usually be found by partially drying, the BR and RR sutures almost invariably need also to have been wetted with xylol or clove oil to show up. The BR sutures are rarely completely straight and may be quite devious, while the BB ones are often partially sinuous.

One specimen shows an extra horizontal suture about half way up the basals, while another has only four interbasal sutures (but the usual five radials).

The first brachial (Br_1) is rectangular or slightly tapering, usually just broader than long. Only four specimens retain parts of some arms beyond the first brachial joint, which appears to be more vulnerable than that of *D. brevis* (though the greater depth of dredging might be responsible for this). The largest of the four (calyx height 5·3 mm) has a complete arm *c.* 23 mm long but may be incompletely regenerated from Br_1 judging by the slight diminution of breadth at the first joint (Fig. 3a). It has pinnules up to 6·0 mm long with up to 15 segments. The first pinnule is usually on Br_8 (i.e. = P_b). A second specimen, calyx height 4·7 mm, has the first pinnule (P_3) on Br_{10} on the single arm remaining, while the smallest, calyx height 2·5 mm, has the first pinnule (P_c) on Br_{12}. All have syzygies alternating regularly with muscular joints throughout the arms remaining. There is a slight lateral flange on Br_2 and $_3$ but the arms are distinctly compressed laterally from the syzygy at 3+4.

Growth changes. In the stalk the maximum distal breadth ranges from 1·2 to 2·5 mm in the present material, tending to increase with growth much more than the proximal breadth, which is 1·0–1·6 mm. Although the longer columnals are relatively longer in smaller specimens and have length/median breadth up to 3·2/1 (at calyx height 2·5 mm), above a calyx height of 4 mm the ratio is fairly restricted, ranging from 1·6 to 2·3/1, with a mean of 1·9/1.

Over most of the size range there is not much change of shape in the calyx ; excepting the largest specimen (see Table 2), the maximum breadth shows a mean of 50% of the height in nine specimens with height 5 mm or more, compared with a mean of 57% in six specimens with height up to 4 mm. However, this largest specimen (height 7·7 mm) is distinctly narrower with a breadth of only 36% and the larger syntype drawn by Cherbonnier (in Gislén, 1947, fig. 3) at a height of 7·4 mm has the breadth *c.* 42%. Beyond *c.* 6 mm height it is possible that the breadth increases more slowly.

Judging from the few specimens with arms, the more proximal pinnules are developed successively, as noted in some other bathycrinids.

Affinities. In spite of its restoration from the synonymy of *Democrinus rawsoni* (Pourtalès) by A. H. Clark in 1909, no proper comparison between *D. parfaiti* and that Caribbean species has been made. A. H. Clark grouped the two as both having the calyx approximately cylindrical but distinguished them by the relative size of the bottom diameter of the calyx in comparison with the diameter of

the radials (*c.* 50% in *D. parfaiti* but more than 66% in *D. rawsoni* from his estimates). However, his concept of *D. parfaiti* was based on Perrier's fig. 192 (1886) (reproduced by Mortensen, 1927 : 20) which gives *c.* 58% from my measurements). Gislén (1938) in his key again emphasized the more conical form of the calyx in *D. parfaiti* and also separated them on the more attenuated form of the columnals in that species (length/breadth 2–3/1, with breadth rarely exceeding 1 mm, as opposed to 1·5–2/1 with breadth >2 mm in *D. rawsoni*). However, out of the present sample of *D. parfaiti*, even the smallest one has the minimum (top) diameter of the stalk just over 1 mm and it may be up to 1·6 mm in the larger ones with the maximum distal diameter up to 2·5 mm.

Unfortunately, out of six samples in the British Museum collections hitherto labelled as *D. rawsoni*, two are probably or certainly *D. parfaiti*, three form part of the type series of *D. brevis* and the last, from Cuba, is also conspecific with *D. brevis*. It is therefore necessary to fall back on the published information concerning *D. rawsoni*, which is rather inadequate. Even so, several significant features can be extracted from it.

Firstly, the form of the single distal stalk attachment from Barbados seen by Pourtalès (1874) is described as having 'the appearance of having been partly attached to a solid body by enlarged surfaces and to have had relatively few radicular cirri', possibly much as in *D. brevis* illustrated here (Fig. 2d), though his fig. 2 shows only some ill-defined truncated branches. He contrasts this attachment with the 'ramifying rootlets' of *Rhizocrinus lofotensis* which, he says, are adapted for anchorage in a loose substrate, as are those of the *Shackleton* specimens of *D. parfaiti* (though the initial division into major branches resembles more closely the root form of *Bathycrinus* than of *Rhizocrinus*). Carpenter (1884, pl. 10, fig. 15) illustrates a peculiar stalk termination of a specimen from off Havana, Cuba, with about eight short, splayed radicular cirri each ending in an irregular expanded disc fixed to bits of substrate (the whole resembling a spider with big flat feet).

Secondly, the columnals do appear relatively broader in Pourtalès' figs 1 and 2 of *D. rawsoni* than they are in *D. parfaiti*, even if the breadth is of similar magnitude (see below under *D. rawsoni*), so Gislén's distinction by this character probably holds good.

Thirdly, Pourtalès' figs 1 and 4 and A. H. Clark's fig. 133 (1915a) of calyces of type material of *D. rawsoni* show not only a nearly cylindrical form of calyx but also no sign of the abrupt constriction near the top found so consistently in the *Shackleton* material and the types of *D. parfaiti*. Also Pourtalès describes the sutures of the calyx as 'plainly visible with a lens of moderate power', those of *D. parfaiti* being only visible with difficulty (sometimes not at all in the case of the BR and RR sutures).

It is also possible that there is a difference in the shape of the arm bases. Pourtalès shows them as broad for about the first six brachials before tapering, as in *D. brevis*, whereas in *D. parfaiti* only Br_2 and Br_3 have a slight lateral flange, the arm apparently narrowing from Br_4.

Of the other Atlantic species of *Democrinus*, *D. brevis*, like *D. rawsoni*, has the stalk attached by a terminal expansion of irregular flattened lobes, relatively stouter

columnals, distinct sutures in the calyx and no sharp constriction around the radials. In addition, its calyx is relatively broad and squat.

A much closer resemblance is shown by *Democrinus conifer* (A. H. Clark, 1909) from off Brazil, particularly in the elongate conical form of the calyx, with an abrupt constriction around the radials. Gislén (1938) was misled by Perrier's description of *D. parfaiti* into distinguishing it from *D. conifer* by having a furrow (constriction) between the radials and basals, not above, as it really is, sometimes markedly so. The calyx height in the holotype of *D. conifer* is as much as 11 mm. Carpenter (1884, pl. 10, figs 3–5) shows a Caribbean specimen (presumably from the *Blake* collections), also with an abrupt constriction in the radials.

Gislén (1938) lists numerous references under the heading of *D. conifer* and synonymizes with it *Rhizocrinus robustus* A. H. Clark, 1909* and *Bythocrinus intermedius* A. H. Clark, 1915. In 1923 A. H. Clark cited records of (*Bythocrinus*) *robustus* from Brazil as well as the Gulf of Mexico (the type locality) and also from the vicinity of Portugal. At least the last record I believe must be referable to *D. parfaiti*. If the stalk attachment of *D. conifer* proves to be root-like, then it will be difficult to maintain it as a valid species distinct from *D. parfaiti*.

Finally, Gislén (1947) has described *Rhizocrinus magnus* from off Tangier (*c.* 36°N, 8°W) in 2150–2300 metres, the holotype lacking the arms and the distal part of the stalk. The shape is very similar to *D. parfaiti*, even to a constriction at the top of the conical calyx, which is 5 mm high, but the sutures of the calyx are evidently so closely fused as to be invisible – hence the inclusion in *Rhizocrinus*. In spite of this, the approximation of locality and the resemblance in shape throw some doubt on the validity of *R. magnus* as distinct from *D. parfaiti* in my opinion.

Distribution. Re-examination of two of Carpenter's *Challenger* specimens from the Azores, named by him *Rhizocrinus rawsoni*, shows that they are conspecific with *D. parfaiti*, which A. H. Clark (1949) has also recorded from the vicinity of these islands. Döderlein's *Valdivia* specimens from south of the Canary Is are also referable to *D. parfaiti*, judging from his illustrations. Unfortunately the only *Porcupine* specimens from off Cape Clear, Ireland, retained in the BM collections are the two very small ones figured by Carpenter (1884, pl. 53, figs 7 and 8) ; with their distinct sutures in the calyx and constriction or hollow around the radials they are most likely also to belong to this species. However, Döderlein's record based on a stalk fragment from the Faeroe Channel is very dubious. The known distribution may therefore be limited to the NE. Atlantic from the Azores eastward between latitudes 24° and 50°N in depths of 870 (?650)–2500 (?3010) metres.

Democrinus rawsoni (Pourtalès)

Rhizocrinus rawsoni Pourtalès, 1874 : 27–31, pl. 5, figs 1–7, 9–12, 14 ; Carpenter, 1884 (pt) : 263 (*Hassler* and probably most *Blake* records), ? pl. 10, figs 6, 7, 15–20.

? *Rhizocrinus sabae* A. H. Clark, 1909 : 675.

Democrinus rawsonii : A. H. Clark, 1915a : 203, 205, figs 133, 138 ; H. L. Clark, 1918 : 16 ; A. H. Clark, 1921 : 26 ; 1923 : 45 ; Gislén, 1938 : 29–30 ; H. L. Clark, 1941 : 7–8. [Non *D. rawsoni* : Gislén, 1928.]

* In listing the echinoderms from the Gulf of Mexico in 1954, A. H. Clark still cites *robustus* as a valid species (of *Democrinus*).

MATERIAL. None. As explained above, all the specimens referred to this species by Carpenter (1884) in the British Museum collections have since been referred to other species of *Democrinus*.

REMARKS. Pourtalès (1874) described this species from several specimens taken west of Barbados. His figure of a calyx (1874, pl. 5, fig. 4) shows an almost cylindrical shape, broadest at about half its height and maintaining a similar breadth to the top of the radials. The maximum breadth is only about 50% of the height (if the drawing is accurate). A. H. Clark's camera lucida drawing (1915a, fig. 133) of a syntype shows a calyx of similarly almost cylindrical but even more elongate form, the maximum breadth only 33% of the height. Although both figures show a slight hollowing in the vicinity of the BR suture, there is no sign in either of an abrupt constriction such as in *D. parfaiti*.

Neither Pourtalès (1874) nor A. H. Clark (1915a) gives any measurements for the calyx but the largest syntype measures 170 mm in length without the arms and the distal extremity of the stalk, which are missing ; the remaining part of the stalk has 63 columnals and is 1·5–2 mm in breadth. Judging from the drawings, if the upper end of the stalk is 1·5 mm broad then the calyx height would be *c.* 4 mm in the one shown by Pourtalès and 6 mm in Clark's. This is a similar magnitude to the specimens of *D. brevis* and *D. parfaiti* described above. In 1921 A. H. Clark described a specimen from the Barbados – Antigua Expedition, closely resembling the type material, having calyx height 4·7 mm (breadth not given) and a stalk of 58 columnals measuring 155 mm in length. H. L. Clark (1918) recorded a specimen from off Havana, Cuba, with calyx 4 mm high and 1·85 mm in (presumably maximum) diameter (46% of the height), the stalk having 60 columnals and measuring 145 mm. Carpenter (1884) gives the calyx height and maximum breadth of a *Blake* specimen as 6 and 2·5 mm, making a relative breadth of 42% at a stalk length of 180 mm, with 68 columnals present. Most of the *Blake* specimens he records were from the southern Caribbean in the vicinity of the type locality but one was from Cuba.

Carpenter treated this species as having a very wide range of form of the calyx but subsequent workers, notably A. H. Clark (1923), have emphasized that it is nearly cylindrical. It is surprising then that A. H. Clark in 1923, when listing the Atlantic crinoids with their ranges, omits *D. brevis* but cites its type locality (off Colon) under the heading of *D. rawsoni* and presumably at that time thought them to be synonymous, in spite of the squat conical calyces in the type material of *D. brevis*. In view of this conflict and the other caribbean species of *Democrinus* which have been described, it is desirable that the material from this area should be reexamined.

DISTRIBUTION. Owing to the confusion of records it is uncertain whether this species extends beyond the Caribbean ; A. H. Clark (1923) gives the depth range as 66–652 metres.

Democrinus sp.

(Fig. 4)

MATERIAL. *Challenger* st. 122C, 09°10'S, 34°49'W (off NE. Brazil), 730 metres ; 1 specimen, BM(NH) reg. no. 85.3.30.29. [Named *R. lofotensis* by Carpenter (1884).]

Atlantis II cruise 31, st. 162A, 08°02′S, 34°03′W–07°56′S, 34°09′W (off NE. Brazil), 1493 metres ; 6 calyces, 2 distal ends of stalks.

Atlantis II cruise 31, st. 167, 07°58′S, 34°17′W–08°50′S ; 943–1007 metres ; 2 calyces.

Atlantis II cruise 31, st. 169A, 08°03′S, 34°23′W–08°02′S, 34°25′W, 587 metres ; 5 calyces and 2 pieces of 'root'.

Atlantis II cruise 60, st. 262A, 36°05·2′S, 52°17·9′W (off Rio de la Plata), 2440–2480 metres ; 1 calyx and pentacrinoid.

The *Challenger* specimen is badly decalcified. Numerical data from the other 13 similarly small specimens are given in Table 3.

TABLE 3

Numerical data from 13 specimens of *Democrinus* sp.

Station	Proximal stalk breadth = calyx minimum breadth	Calyx height (maximum)	Calyx breadth (maximum)	Br. as % of Ht.
162A	0·33	2·17	1·58	73
262A	0·45	2·10	1·64	78
167	0·54	2·08	1·50	72
162A	0·33	2·00	1·42	71
169A	0·29	1·92	1·54	80
169A	0·42	1·83	1·25	68
169A	0·33	1·82	1·20	66
162A*	0·42	1·75	1·17	67
162A	0·30	1·58	1·29	82
162A	0·27	1·46	1·25	86
167	0·37	1·42	1·21	85
162A	0·25	1·42	1·17	82
169A	0·33	1·33	1·17	88

* This specimen is the six-armed one.

DESCRIPTION. One calyx from st. 162A (Fig. 4b, the eighth in Table 3) is six-rayed and also differs from the rest in having the interbasal (BB) sutures distinct and regular, as in *Democrinus chuni*. In the last and smallest specimen in Table 3 (Fig. 4c) three very irregular BB sutures can just be discerned when partially dried after wetting with xylol and in a few other specimens there are also traces of these sutures. Otherwise in the remaining specimens only the BR and RR sutures are distinguishable (Fig. 4a) and even these sometimes only appear after xylol treatment. This contrasts with *Rhizocrinus lofotensis* M. Sars, ranging from Norway to NE. America, which has the BR and RR sutures distinguishable in only a minority of specimens and the BB ones not at all. Gislén (1938) diagnosed *Rhizocrinus* Sars as having the BB sutures fused and the radials 'very closely connected with and most often coalesced with' the basals, as opposed to *Democrinus* Perrier with 'basals separated by distinct sutures' and radials 'always separated from each other and the basal cup by distinct sutures'. The six-rayed specimen therefore runs down to *Democrinus* but not the rest ; the visibility of its sutures could be correlated with

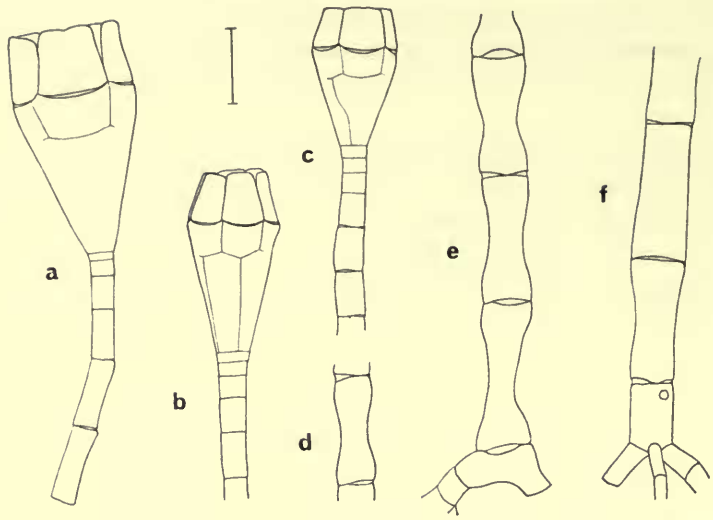

FIG. 4. *Democrinus* sp. a–c. Calyces and adjacent ossicles of the first, eighth and last specimens in Table 3. d. Thirteenth columnal of c. e and f. Distal ends of two stalks (possibly of another species). [The scale measures 1 mm.]

the additional one. As noted above, the sutures in the calyx of *Democrinus parfaiti* Perrier – the type-species of the genus – may be very hard to distinguish so the character is not altogether reliable.

The shape of the normal calyces is more or less conical (fig. 4a), though the largest one is slightly swollen near the top of the radials. However, about five specimens have somewhat deformed calyces with irregular bulges or constrictions. Two from st. 162A have perforations in the calyx and the *Challenger* specimen has two large round holes with a relatively huge parasitic gastropod still hanging from one of them. Possibly the other specimens have also been parasitized. The maximum breadth of the calyx ranges from 66 to 88% of the maximum height in the 13 specimens, with a mean of 77%. There appears to be a relative decrease in breadth compared to height during growth, as in *R. lofotensis* and in the similarly small South and East African species *Democrinus chuni* (Döderlein). The height of the basal ring forms *c.* 65% of the maximum calyx height.

In all the specimens the arms are broken after the first brachial, which ossicle is relatively narrow, even in the largest specimen only slightly broader proximally than long. It should be noted that, although Gislén (1938) also distinguished *Rhizocrinus* by the relatively long Br_1, as here, I found in 1972 that *D. chuni* has length/breadth of the first brachial ranging from 0·6 to 1·7/1.

As for the stalks, only a few proximal columnals are short, the fourth one being usually the first to have length exceeding breadth. The length increases markedly and by the tenth the length/median breadth ratio is usually 3·5–4·0/1. No complete stalk remains. Some of the broken middle or distal pieces have very swollen joints (Fig. 4e) while others are only slightly so (Fig. 4f) and it is possible that two species

might be represented. It is significant that the distal ends of the stalks present bifurcate or trifurcate into relatively large branches, with few, if any, small radicular cirri arising from the columnals immediately above the division, in contrast to *Rhizocrinus lofotensis* where the column usually ends abruptly without producing any large branches and numerous fine radicular cirri arise on most columnals of the distal half of the stalk (see Sars, 1868, pl. 1, figs 1, 6, 7, 17 and 19, though the specimen in fig. 16 does have a large branch from the penultimate columnal). This is much more like the rooting form of *Democrinus chuni* and *D. parfaiti*.

Affinities. Two other species remain in *Rhizocrinus* in addition to *R. lofotensis*, namely *R. minimus* (Döderlein, 1907) from the East Indies and *R. magnus* Gislén, 1947 from off Morocco. Both are known only from single specimens lacking the distal end of the stalk but both agree with *R. lofotensis* in lacking any distinct sutures in the calyx. Since the present specimens have at least the RR and BR sutures visible (if not some or all of the BB ones) and branching distal ends to the stalks, they clearly have greater affinity with *Democrinus chuni* than with *Rhizocrinus lofotensis*. In spite of the wording of Gislén's (1938) diagnoses I think that they should be referred to *Democrinus*. The distinction of these two genera needs further study when more material is available.

Order COMATULIDA

Family **ATELECRINIDAE**

Atelecrinus sp. juv.

(Fig. 5)

Material. *Atlantis II* cruise 60, st. 242, 38°16·9′S, 51°56·1′W (SE. of Rio de la Plata, Argentina), 4382–4402 metres ; 1 pentacrinoid.

Atlantis II, cruise 60, st. 256, 37°40·9′S, 52°19·3′W, 3906–3917 metres ; 1 post-pentacrinoid and 1 pentacrinoid.

Atlantis II cruise 60, st. 262A, 36°05·2′S, 52°17·9′W, 2440–2480 metres ; 1 pentacrinoid.

[Additionally some of the 25 pentacrinoids from st. 247A may belong here rather than in *Bathycrinus australis*.]

The post-pentacrinoid (Fig. 5a) has probably only recently broken free of its stalk, though the perfectly flat broad apex of the centrodorsal shows no perforation. The breadth is 0·6 mm, whereas the height is less at this stage. There were probably X cirri arranged in a zig-zag row around the side ; between the five adapical ones the stereom extends into somewhat irregular lobes.

Two intact cirri remain, both with 14 segments, all but the first one longer than broad. The larger one measures 6·8 mm and its longest segment has length/median breadth 0·83/0·12 mm (*c.* 7/1). The terminal claw is almost straight and has a blunted tip.

The calyx is hyocrinid-like, the postradial series being distinctly separated laterally so that the upper ends of the radials extend between them. The maximum

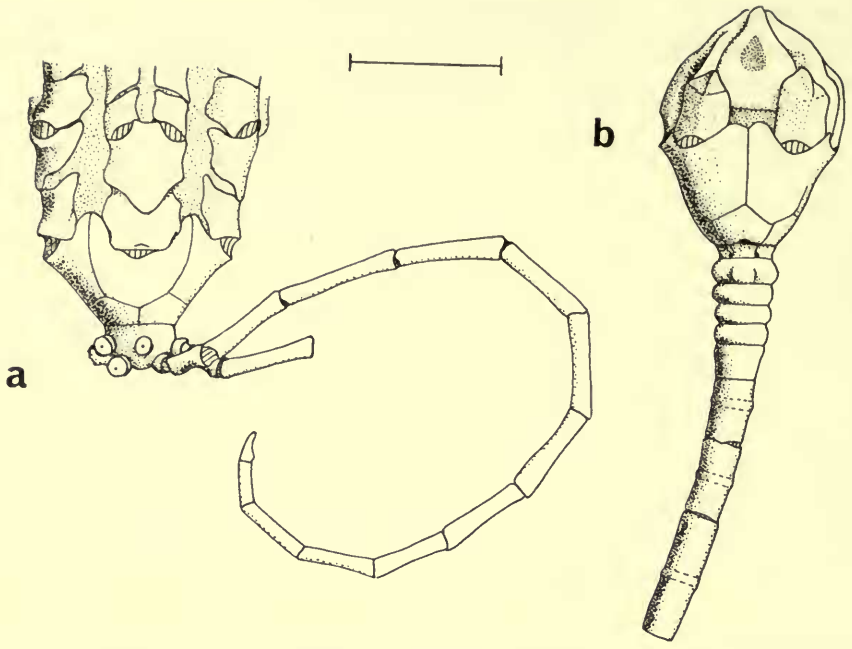

FIG. 5. *Atelecrinus* sp. a. *Atlantis II* st. 256, post-pentacrinoid, viewed radially. b. st. 242, pentacrinoid, viewed interradially. [The scale measures 1 mm.]

breadth across the top of the radials is 1·3 mm and the height interradially 0·7 mm. The basals still form a complete ring and make about a third of the height of the calyx.

The two arms of each pair are slightly spaced, corresponding to the condition of the division series. The arm length was probably *c.* 8 mm but all are broken by the sixteenth brachial. Proximal syzygies are at 3+4 and 9+10. The breadth at 3+4 is 0·25 mm. No pinnules are developed before Br_{14} (P_6).

The pentacrinoid from the same station (256) has the calyx very similar except that the radials are relatively longer. Only the IBr_1 have so far developed from the radials. The uppermost columnal is slightly swollen.

The pentacrinoid from st. 242 (Fig. 5b) is a little more advanced with rudiments of the IBr_2 forming and the uppermost columnal markedly swollen in each interradius, heralding the first cirri. Only eight columnals remain, of which the last three are longer than broad, the eighth with length 3·5 × breadth. The three lower segments each have a slightly raised belt, usually medially. The lower ends of the basals are distinctly constricted. Possibly the centrodorsal is liable to grow up over this area.

The generic position of these specimens is indicated by several factors, the completeness of the basal ring, even at the post-pentacrinoid stage, the very attenuated form of the cirri and the retarded development of the pinnules, in comparison with young Antedonidae.

Atelecrinus balanoides P. H. Carpenter (see Clark & Clark, 1967 : 823) was taken by the *Challenger* off Pernambuco, Brazil (*c.* 9°S), and may well extend south to these latitudes.

Family **ANTEDONIDAE**

? ***Hybometra senta*** A. H. Clark

Hybometra senta A. H. Clark, 1913 : 54 ; A. H. & A. M. Clark, 1967 : 550–552, fig. 31.

MATERIAL. *Atlantis II* cruise 42, st. 202, 08°56′S, 12°15′E–08°46′S, 12°47′E (off Angola), 1427–1643 metres ; *c.* 50 poorly preserved specimens.

The holotype and only recorded specimen of *Hybometra senta* was from Brazil in only 42 metres. It is considerably larger than these specimens, arm breadth at Br_{3+4} 2·0 mm and arm length 90+ mm, whereas the largest of these have the breadth *c.* 1·25 mm and arm length *c.* 55 mm.

There is agreement between them in the spinose and flared division series and brachials and in the arrangement of the cirri in fairly regular vertical columns (especially interradially) on the conical centrodorsal, though the vertical height usually just exceeds the maximum breadth in these specimens, whereas in the holotype it is relatively lower, height/breadth 3·2/4·1 mm. The cirri of the holotype are unfortunately known. In the present specimens they number up to XC, forming four columns of four (sometimes five) sockets in each radius. The cirri have up to 36 segments, all except the first one longer than broad, the longest (about the fifth) with length/median breadth 1·5/0·35 mm = 4·28/1. All the segments are very expanded at their distal ends ; the opposing spine is well developed and the terminal claw slightly curved. The total length is up to 22 mm.

The division series are slightly flared and spinose at their distal edges but the brachials soon develop long spiny tufts. The IBr_1 and Br_1 are markedly constricted laterally, the succeeding ossicle markedly projecting.

P_1 has well over 20 segments and measures 6+ mm ; the segments are elongated and spinose. P_2 and the genital pinnules were probably smaller and with even more slender segments.

Of the few crinoids recorded from West Africa, *Leptometra celtica* has a similarly often conical centrodorsal and its cirri and pinnules have similar proportions ; however, the curved terminal claw on the cirri of these specimens and the spinose flared ossicles serve to distinguish them.

Leptometra phalangium (J. Müller)

Alecto phalangium J. Müller, 1841 : 182.
Leptometra phalangium : A. H. & A. M. Clark, 1967 : 553–564, fig. 32a, b.

MATERIAL. *Atlantis II* cruise 59, st. 211, 34°41·5′N, 17°28′E (Mediterranean, N. from Libya), 2834–2789 metres ; 1 poorly preserved specimen.

The previous deepest record in the Mediterranean for *Leptometra phalangium* is 1292 metres, which is considerably exceeded by the present one.

The centrodorsal is relatively low with only about X cirri in one irregular ring Possibly this is correlated with the depth and quieter water.

The smooth attenuated cirrus and pinnule segments agree with *L. phalangium.*

Indeterminable Antedonidae

Some small, more or less broken, Antedonidae belonging to three different species, probably all of Bathymetrinae, were taken respectively at the following stations :
1. *Atlantis II* cruise 60, st. 256, 37°40·9′S, 52°19·3W (off Rio de la Plata), 3906–3917 metres ; 7 specimens. St. 259A, 37°13·3′S, 52°45′W, 3305–3317 metres ; 6 specimens.
2. *Atlantis II* cruise 31, st. 162A, 08°02′S, 34°03′W–07°56′S, 34°09′W (off NE. Brazil), 1493 metres ; 1 specimen.
3. *Chain* cruise 106, st. 328, 50°04·7′N, 15°44·8′W (SW. from Cape Clear, Ireland), 4426–4435 metres ; 5 specimens.

Species 1. The largest specimen has arms 15+ (possibly *c.* 25) mm long ; the arm breadth at 3+4 is 0·9 mm and the length from the IBr_1 to Br_9 (inclusive) is 7·2 mm. The centrodorsal is low blunt conical with cirrus sockets irregular in position. The longest cirri have up to 23 fairly long segments, total length up to 11·2 mm with the longest segments having length/median breadth 2·5/1 ; they are flared at the joints. The division series and arms are laterally constricted and rounded, the division series finely rugose, the brachials soon developing a small tuft of spines at the flared distal end. All the proximal pinnules are broken ; the first three probably had at least 12 segments, P_3 is the first genital pinnule and much larger than the preceding ones with segments 4–6 relatively longer and broader, rather as in *Isometra angustipinna* (P. H. Carpenter) from off Uruguay. However, that species at a similar size has only five or six segments in the first two pinnules and a large flange on the second and third segments of the genital pinnules. There is also some resemblance to the holotype of *Phrixometra longipinna* (P. H. Carpenter), also known from off Uruguay.

Species 2. The single specimen has the arm breadth at 3+4 only *c.* 0·5 mm. It has a low conical centrodorsal with irregularly arranged sockets ; the dorsal pole is crowned with truncated hyaline papillae. The cirri are very attenuated with up to 19 segments, which are long, compressed and distally flared. The opposing spine is sharp and the terminal claw slender and curved.

Species 3. The three larger specimens have the arm breadth at 3+4 *c.* 0·7 mm. The centrodorsal is low conical and some of the cirrus sockets are arranged in vertical columns (more like the Zenometrinae). The cirri have up to 15 relatively short segments, not more than twice as long as the median breadth, markedly flared dorsally and keeled distally. Most of the ossicles are almost smooth, only very slightly rugose. The pinnules are very attentuated ; the genital pinnules, starting with P_3, have particularly slender segments. The specimens have some affinity with *Orthometra hibernica* (A. H. Clark) (see A. M. Clark, 1970 : 34) though the ossicles are more attenuated, as well as with *Trichometra delicata* A. H. Clark (see A. M. Clark,

1970 : 48) though the ossicles are smoother and the latter species has P_2 the first genital pinnule.

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